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§35. Observation of Internal Structure of Edge MHD Modes in High Beta Plasmas on LHD

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In LHD, Edge MHD modes such as m/n = 1/1, 3/4, 2/3 and 1/2 are excited near the plasma edge region in magnetic hill, with the increase in the plasma beta value [1]. These edge MHD modes sometimes interrupt the increase in the stored energy in high beta regime. In particular, the edge MHD modes are suddenly destabilized just after L-H transition which leads to the formation of edge transport barrier having a steep pressure gradient [1, 2]. To clarify characteristics of edge MHD modes and minimize the effects on plasma confinement, measurements of the internal structure, growth rate and so on are crucially required.

In LHD, we have employed eight sets of 20-channel soft-X-ray (SX) detector array in order to measure the internal structure of the edge MHD modes. An example of these SX detector array systems is shown in Fig. 1. This system is installed inside the vacuum vessel in the vertically elongated section of LHD. The detector array is a silicon PIN photodiode array which consists of 20ch active areas arranged in one dimension. A beryllium foil with 8μm or 15μm thickness is attached in the front of the system to shut visible and vacuum ultra violet emissions. The viewing sight of the detector system is adjusted through a collimator slit, as shown in Fig.1.

Figures 2(a)-2(d) show the radial profile of SX intensity I_{sx}, the fluctuation amplitude δI_{sx} have high coherence with the observed m/n = 1/1 and 2/3 magnetic fluctuations in a typical high beta hydrogen plasma heated by NBI heating. The rational surfaces of these edge MHD modes locate in the plasma edge region ($<r>/<a> = \rho > 0.8$). The SX fluctuation δI_{sx} is derived by numerical filtering around the frequency range of high coherence with the magnetic fluctuations, and is averaged over a time window of 20 ms. The relative amplitude $\delta I_{sx}/I_{sx}$ of m/n = 1/1 and m/n = 2/3 modes increases rapidly toward the plasma edge, as shown in Figs.2(c) and 2(d). The peak of δI_{sx} for respective mode locates slightly inside that of the rational surface, which is caused by the path integral effect in SX signals. Moreover, δI_{sx} of m/n = 2/3 mode has a peak in the plasma central region (Fig.2(b)). This is also attributed to the path integral effect. The relative amplitude of m/n = 2/3 mode decreases more rapidly toward the plasma center than that of m/n = 1/1 mode. This is consistent with the radial dependence of the eigenfunction with different m number, although $\delta I_{sx}/I_{sx}$ or even $\delta I_{sx}/|\nabla I_{sx}|$ does not necessarily correspond to an eigenfunction of the MHD mode because of the path integral effect.

The phase relation among SX fluctuation signals obtained by a SX array will give information of m-number. As shown in Figs. 2(e) and 2(f), the phase difference between SX channels in inboard and outboard plasma edges is roughly ~2π for m/n = 2/3, i.e. the m-number is even, and is ~π for m/n = 1/1, i.e. the m-number is odd. They are consistent with the m-number determined with magnetic probe array.

In conclusion, the edge MHD modes were clearly detected by SX detector arrays as well as magnetic probes. The relative amplitude $\delta I_{sx}/I_{sx}$ of edge MHD modes such as m/n = 2/3 and 1/1 increases rapidly toward the plasma edge, which clearly indicates a character of edge mode. The radial variation of $\delta I_{sx}/I_{sx}$ depends on the m-number. In order to clarify the characteristics of edge MHD modes and their impact on plasma confinement, we need the detailed comparison between experimental data such as SX data and theoretical results on edge MHD modes obtained by MHD stability codes for three-dimensional plasma such as CAS3D3 code [3].

Reference

1) Toi, K. *et al.*, Nucl. Fusion **44**, 217 (2004).
2) Toi, K. *et al.*, Phys. Plasma **12**, 020701-1 (2005).
3) Nakajima, N., 20th IAEA Energy Conf., Villamoura, TH/56(2004).

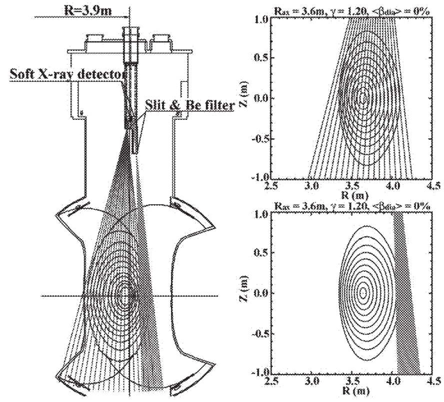

Fig. 1 SX detector array system in LHD. 40 lines of sight by two SX-ray detector arrays are drawn.

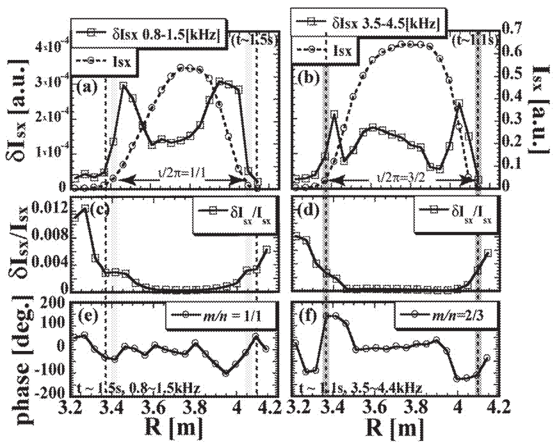

Fig. 2 Radial profiles of SX intensity (I_{sx}), fluctuation amplitude (δI_{sx}) by edge MHD modes (m/n = 1/1 and 2/3) and phase difference between SX channels. The vertical dotted lines indicate the LCFS in the vacuum field. Thin vertical lines stand for the rational surfaces of $\iota/2\pi$ = 1 and 3/2.